

COMPASS AND COMMUNICATION SYSTEM

Statement of Government Interest

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

Cross Reference to Related Application

This is a continuation-in-part of co-pending U. S. patent application entitled "Small Head-Mounted Compass System With Optical Display" by William d. Olstad et al., U.S. Patent and Trademark Office Serial No. 10/699,426 (NC 84835), filed November 3, 2003 and incorporates all references and information thereof by reference herein.

Background of the Invention

This invention relates to a system for indicating horizontal orientation of an operator under conditions of impaired visibility. More particularly, this invention relates to a system partially mounted on headgear or equipment (dive masks, goggles, firefighting masks, helmets, head straps, backpacks, portable equipments) for indicating horizontal orientation or azimuth of a operator-wearer (diver and other workers) for real-time evaluations and advice by remote observers.

Some skilled workers such as divers, miners, rescue personnel etc. frequently perform their physically demanding tasks under highly dangerous and confined conditions that may include limited visibility. Often, the dangers created by these conditions are exacerbated by technically sophisticated/dangerous equipment and other hazardous

1 circumstances at the recovery or work site. During a strenuous and  
2 intensive effort, situations can arise outside of the expertise of the  
3 worker that need inputs from one or more cognizant experts to  
4 successfully complete a task. The effectiveness of the advice from the  
5 expert usually is based on information from the worker that is  
6 unmistakable.

7       For example, during salvage of complicated and highly explosive  
8 ordnance from great depths, divers often need technical assistance and  
9 guidance from structural experts concerning specifics of the  
10 construction of the craft that carried the ordnance to safely remove  
11 the items of interest. Technical assistance from ordnance experts may  
12 also be needed for safely handling and bringing the ordnance items to  
13 the surface after their removal.

14       The technical experts located a safe distance away can transmit  
15 needed technical information to a diver or other worker at the site by  
16 contemporary communication systems. However, since much of a work site  
17 can be at least partially obscured, the diver often may be unable to  
18 describe his location or the surrounding structures with sufficient  
19 accuracy to enable the distant experts to correctly evaluate the  
20 situation and properly advise the diver. Existing techniques for  
21 getting diver azimuth to surface require the diver to stop what he is  
22 doing, find his compass, orient compass, read compass (if possible)  
23 and verbally transmit reading to surface using a hardwire or acoustic  
24 communication system. This process is awkward, inefficient, prone to  
25 error, a potential safety hazard, and is not real time.

26       The experts on the surface may be unable to determine if a diver

1 is looking one way toward one end of a submerged chamber at an empty  
2 container or the other way at a similarly appearing container filled  
3 with unstable explosives at the other end of the chamber. Disastrous  
4 consequences could follow by giving the wrong technical advice since  
5 it is not clear exactly which way or where the diver is looking.

6 Thus, in accordance with this inventive concept, a need has been  
7 recognized in the state of the art for a system providing continuous,  
8 compass data representative of horizontal orientation or azimuth of a  
9 worker such as a diver and communicating this azimuth data to a remote  
10 location for evaluation and responsive action.

#### 11 Objects and Summary of the Invention

12 An object of the invention is to provide a system providing  
13 continuous, compass data representative of horizontal orientation or  
14 azimuth of a diver and communicating this azimuth data to a remote  
15 location for evaluation and responsive action.

16 Another object is to provide a system providing information of  
17 azimuth that does not require an operator to maintain a predetermined  
18 physical attitude.

19 Another objective is to provide a system for providing data  
20 representative of the azimuth of a diver for remote evaluation of a  
21 task and advice concerning the task by technical experts.

22 Another object of the invention is to provide a compact and  
23 rugged system partially carried on a headgear or other equipment to  
24 provide data representative of heading or direction faced for more  
25 responsive evaluation of reported information at a remote location.

26 Another object of the invention is to provide a compact system

1 having a compass sensor module on a worker and communications module  
2 linking the compass module to a remote location.

3 Another object of the invention is to provide a compass and  
4 communications system to help perform undersea tasks in a safer and  
5 more efficient manner with better and more thorough results.

6 These and other objects of the invention will become more readily  
7 apparent from the ensuing specification when taken in conjunction with  
8 the appended claims.

9 Accordingly, the present invention is for a compass and  
10 communication system to transmit azimuth data representative of  
11 heading of an operator such as a diver to a remote location on a  
12 surface craft. A compass sensor module has a waterproof housing and a  
13 mounting mechanism on the housing to engage a headgear worn at the  
14 back of a diver's head. A two-axis gimbal mechanism inside the  
15 waterproof housing has a protective housing connected to the  
16 waterproof housing and contains ring structure and two orthogonal axis  
17 structures. A magnetic field sensor unit is mounted on one of the axis  
18 structures and provides magnetic field data signals representative of  
19 the direction or azimuth faced by the diver. The mounting mechanism  
20 transmits horizontal yawing motions of the diver to the gimbal  
21 mechanism and magnetic field sensor unit. A processor electronics  
22 section of the compass sensor module is connected to the magnetic  
23 field sensor unit to provide data signals representative of azimuth  
24 from the magnetic field data signals. A data transmission module has  
25 an electrically insulated conductor connected to the compass sensor  
26 module and an amplifier stage for amplifying an electromagnetic form

1 of the azimuth data signals and an electrically insulated cable  
2 extends from the amplifier stage for remotely transmitting the  
3 electromagnetic azimuth signals. An acoustic transducer in the data  
4 transmission module is connected to the amplifier stage to transmit  
5 the azimuth data signals as acoustic signals through ambient water to  
6 the remote location. A transceiver/display console at the remote craft  
7 is connected to the cable and water to receive and display the  
8 remotely transmitted azimuth data signals.

9 Brief Description of the Drawings

10 FIG. 1 is a schematic side view of the compass and communication  
11 system of the invention having a compass sensor module mounted on the  
12 back part of a headgear such as a diving face mask and a  
13 communications module mounted partially on an operator's equipment  
14 package.

15 FIG. 2 is a block diagram of the compass sensor module of the  
16 invention.

17 FIG. 3 is a schematic cross-sectional top view of a two-axis  
18 damped mechanical gimbal mechanism supporting a magnetic field sensing  
19 unit taken generally along line 3-3 in FIG. 2.

20 FIG. 4 is a schematic cross-sectional side view of a two-axis  
21 damped mechanical gimbal mechanism supporting a magnetic field sensing  
22 unit taken generally along line 4-4 in FIG. 3.

23 Description of the Preferred Embodiments

24 Referring to FIG. 1, compass and communication system 10 of the  
25 invention is for communicating data (shown as arrow 12) representative  
26 of heading in the horizontal plane or azimuth of a diver 14 submerged

1 at a work site 16 that can be deep in water 18. Compass and  
2 communication system 10 can input azimuth data 12 to diver-carried  
3 equipment 17 that may be used to perform tasks at work site 16 or  
4 could input data 12 to other operator equipment such as sonar, head-  
5 mounted display, etc. that could utilize such data 12 at the site.

6 Compass and communication system 10 can also be used to provide  
7 azimuth data 12 for other workers such as miners underground,  
8 firefighters and/or rescue workers in visually challenging  
9 surroundings (i.e. in darkness, turbid water, smoke, fog, or other  
10 obscurants) or other location that is not observable from without.

11 Compass and communication system 10 generates and transmits data  
12 12 representative of azimuth of the worker-diver 14 to  
13 transceiver/display console 19 at a remote location 20, such a surface  
14 support craft 22 on water 18 or to submerged platform (not shown)  
15 during clandestine operations. Azimuth data 12 at remote location 20  
16 can be viewed by technical experts in marine geology, structures, and  
17 ordnance, for example. Because a diver's heading often is  
18 indeterminable during diving operations, azimuth data 12 can be the  
19 only means available to apprise the observers which direction diver 14  
20 is looking and which side of a structure or chamber in a sunken craft  
21 is being observed. Consequently, observers having azimuth data 12 are  
22 better informed to evaluate additional oral and/or visual  
23 communications from diver 14 and can give diver 14 more meaningful  
24 technical guidance regarding safer and more effective salvage or work  
25 procedures may be given to diver 14.

26 Compass and communication system 10 has a compass sensor module

24 that generates azimuth data 12 for transmission through water 18 or air 26 via a data-transmission module 28. Compass sensor module 24 is mounted at the back 30 of the head 31 on a headgear 32 that can include straps connected to diving facemasks (as depicted), goggles, firefighting masks, helmets, etc. and stand-alone head-strap-and-bracket assemblies. Optionally, compass sensor module 24 could be mounted on diver-carried equipment 17 for performing tasks at work site 16 or could input data 12 to other operator equipment such as sonar, head-mounted display, or compass sensor module 24 could be mounted on a portable life-support apparatus 34 such as a compressed air tank, re-breather unit, etc. to indicate the direction diver 14 is facing.

Compass sensor module 24 has an electrically insulated conductor 36 connected to feed data 12 to data-transmission module 28 that partially can be held by diver 14. Data-transmission module 28 also could be located partially on head 31 alongside of compass sensor module 24 or be mounted on equipment 17 or life-support apparatus 34.

Referring also to FIG. 2, compass sensor module 24 can be substantially the same as disclosed with regard to the compass system in the referenced co-pending application supra and can be contained in a small waterproof housing 38 that may be depth rated to about 200 feet in salt water. Compass sensor module 24 has a clamp-like mounting mechanism 40 to hold module 24 on headgear 32 or on life support apparatus 34. Compass sensor module 24 might also be mounted on diver-carried equipment 17, for example a film or video camera or search sonar. Azimuth data 12 representative of compass headings could be

1 sent topside along with scanned video/sonar information data to permit  
2 correlation of the scanned information data and the azimuth data 12  
3 for more responsive real-time evaluations by experts topside.

4 Waterproof housing 38 of compass sensor module 24 contains a  
5 miniature electronic, two-axis, magnetic field sensor unit 42 which  
6 provides magnetic field data signals (shown as arrow 44) over  
7 electrical cable 46. Magnetic field data signals 44 are indicative or  
8 representative of the direction or azimuth faced by diver-operator 14.  
9 A typical, commercially available off the shelf two-axis magnetic  
10 field sensor module that can be used for magnetic field sensor module  
11 42 is known as the PNI MicroMag 2-axis Magnetic Sensor Module Part  
12 Number 11594 manufactured by PNI Corporation of 5464 Skylane Blvd.,  
13 Suite A, Santa Rosa, CA 95403.

14 Magnetic field sensor unit 42 is mounted on a two-axis gimbal  
15 mechanism 48 in waterproof housing 38 to allow a wide range of  
16 movement by diver 14 without degrading the accuracy of magnetic field  
17 sensor unit 42. Two-axis gimbal mechanism 48 can be a scaled-down  
18 version of many well known mechanically gimbaled and damped self-  
19 leveling systems. These leveling systems create damped, substantially  
20 level platforms for instrumentations, and typically, they are used as  
21 the supports for ships' compasses to dampen motions from them, or they  
22 may be for gyros or other applications where such supports are needed.  
23 See for example U.S. Patent No. 4,318,522.

24 Two-axis gimbal mechanism 48 could be like the gimbal of prior  
25 art shown in FIG. 1 of the '522 patent. Two-axis gimbal mechanism and  
26 could provide the requisite leveling and yaw detection (horizontal,



1 azimuth sensing) capabilities for magnetic field sensor unit 42 by  
2 miniaturizing the '522 structure of FIG. 1 and substituting magnetic  
3 field sensing unit 42 for the object that looks like a rolling-pin.  
4 Miniaturization of such a self leveling system to meet the size  
5 constraints of compass sensor module 24 is within the scope of one  
6 skilled in the art without calling for anything more than the exercise  
7 of ordinary skill and does not require undue experimentation. The  
8 details of mounting magnetic field sensor module in two axis gimbal  
9 mechanism are set forth in the above referenced co-pending application  
10 and are incorporated by reference herein.

11 Referring also to FIGS. 3 and 4, magnetic field sensor unit 42 is  
12 mounted in a protective housing 50 of gimbal mechanism 48 via a ring  
13 structure 52 coupled to two orthogonal axis structures 54 and 56 of  
14 gimbal mechanism 48. Pivot points 49 are at opposite ends of axis  
15 structure 54 to allow rolling motions of magnetic field sensor unit  
16 42, and pivot points 51 are at opposite ends of axis structure 56 to  
17 allow pitching motions of magnetic field sensor unit 42. Thus,  
18 magnetic field sensor unit 42 stays substantially level regardless of  
19 the pitch and roll of compass sensor module 24 during movement of  
20 diver-operator 14. A ballasting counterweight 58 is connected to the  
21 bottom of magnetic field sensor unit 42. Counterweight 58 is rigidly  
22 attached to and hangs from unit 42 and helps keep unit 42 level and  
23 prevents oscillations of unit 42 by pitching and rolling motions of  
24 diver 14. Protective, sealed housing 50 can be filled with an oil-like  
25 non-reactive fluid 60 to dampen the movement of magnetic field sensor  
26 unit 42 so that it does not oscillate as diver 14 goes from one place

1 to another and/or performs tasks. These features allow diver 14 a wide  
2 range of pitch and roll motions of up to  $\pm 90^\circ$  without degrading the  
3 accuracy of magnetic field sensor unit 42.

4 Protective housing 50 is connected at points 62 to waterproof  
5 housing 38 (only two of which are depicted in FIGS. 2 and 3), and  
6 housing 38 is securely connected to headgear 32 at the back 30 of head  
7 31 by mounting mechanism 40. Consequently, any horizontal yawing  
8 motions (or changes in azimuth) of diver 16 are transmitted to gimbal  
9 mechanism 48 and magnetic field sensor unit 42 so that the azimuth or  
10 direction diver 14 is facing can be sensed by sensor unit 42 that  
11 generates responsive magnetic field data signals 44. This generation  
12 is because yawing motions in the horizontal plane (changes in azimuth)  
13 by diver 1416 are not compensated for by gimbal mechanism 48. Thus,  
14 magnetic field sensor unit 42 is able to sense rotational motion and  
15 different directional headings or facings of diver 14 as diver 14  
16 turns left or right (yawing motion). Magnetic field sensor unit 42  
17 responsively generates directional magnetic field data signals 44 that  
18 can be representative of the azimuth or direction diver 14 faces in  
19 the horizontal plane during progression from one location to another  
20 or while at a particular undersea location.

21 A processor electronics section 64 is connected to magnetic field  
22 sensor unit 42 via electrical cable 46 to receive magnetic field data  
23 signals 44. Processor section 64 reads magnetic field data signals 44,  
24 makes calculations using previously stored calibration data to yield  
25 the compass heading (azimuth), and provides an output as  
26 representative azimuth data signals (shown as arrow 12) in the proper

1 format to data transmission module 28 over its electrically insulated  
2 conductor 36. Optionally, compass sensor module 24 can also have a  
3 small, multi-function wireless RF/acoustic transmitter 66 to transmit  
4 data signals 12 in electromagnetic form 66A a short distance through  
5 water 18 to a small wireless RF receiver 67 of data transmission  
6 module 28 that is connected to amplifier 76. As a further option,  
7 multi-function RF/acoustic transmitter 68 in compass sensor module 24  
8 could acoustically transmit data signals 12 through acoustic  
9 transducer 68 as acoustic signals 69 through water 18 to acoustic  
10 transducer/transceiver 86 in data transmission module 28, or directly  
11 transmit acoustic signals 69 to an acoustic transducer transceiver 70  
12 on remotely located craft 22. However, an unacceptable number of  
13 additional batteries might be needed at module 24 for directly,  
14 acoustically transmitting to craft 22.

15 Compass sensor module 24 has a switch 71 connected to processor  
16 section 64. A push-button 72 from switch 71 extends through housing 38  
17 to permit diver-operator 14 to selectively turn-on or turn-off compass  
18 sensor module 24 as desired. Button 72 of switch 71 is coupled to  
19 processor section 64 that is connected to battery 74 for electrical  
20 power when diver 14 pushes button 72 to turn-on compass sensor module  
21 24. Processor section 64 also connects magnetic field sensing unit 42  
22 to battery 74 via electrical cable 46 to activate it when button 72 is  
23 displaced by diver 14.

24 Representative data signals 12 from compass sensor module 24 are  
25 connected to a data transmission module 28 via its conductor 36 or  
26 through water 18. Data transmission module 28 is shown as being

1 partially hand held by diver 14 along with equipment package 17.  
2 Module 28 and/or equipment 17 can be carried or otherwise transported  
3 by diver 14 at other places on the body or by undersea transport  
4 vehicles at or near the work site.

5 Data transmission module 28 includes an interconnected amplifier  
6 76 and battery power supply 78 connected to conductor 36 and a  
7 remotely extending electrically insulated cable 80. Amplified data  
8 signals 12 from amplifier 76 are coupled via cable 80 to  
9 transceiver/display console 19 on craft 22 for display and evaluation  
10 or relay of azimuth data 12 via RF antenna 84 to another remote  
11 location or satellite (not shown). Data transmission module 28 could  
12 additionally have an acoustic transducer/transceiver 86 for  
13 transmitting data signals 12 as acoustic signals 88 through ambient  
14 water 18 to acoustic transducer/transceiver 70 connected to  
15 transceiver/display console 19 or to appropriate acoustic receivers  
16 carried by others in water 18. Either mode of transmission assures  
17 that technical observers on craft 22 can use the information of  
18 azimuth data signals 12 and be apprised of the direction faced by  
19 diver 14 at work site 16.

20 In operation, diver-operator 14 turns on compass sensor module 24  
21 by pushing push-button 72 of switch 71. The horizontal X and Y  
22 components of the earth's magnetic field are sensed by magnetic field  
23 sensor unit 42 which is kept steady and level by being mounted on two-  
24 axis damped, mechanical gimbal mechanism 48. Magnetic field signals 44  
25 are generated and are coupled over cable 46 to processor electronics  
26 section 64 which reads signals 44 and generates compass heading or

1 azimuth data signals 12 based on previously stored calibration data.  
2 Processor section 64 couples representative compass heading azimuth  
3 data signals 12 via cable 36 to to data transmission module 28 where  
4 data signals 12 are transmitted remotely via cable 80 or water 18 to  
5 console 19 on craft 22. There data 12 can be displayed for evaluation  
6 and responsive action by technical experts or relayed via antenna 92  
7 to a more distant facility.

8 Compass and communication system 10 of the invention is compact  
9 and out-of-the-way to not distract a worker. System 10 of the  
10 invention does not interfere with the completion of tasks in intense  
11 work environments under dangerous, mentally and physically demanding  
12 conditions of obscured visibility that may approach zero. Miners and  
13 rescue workers can also benefit from being equipped with compass and  
14 communication system in their dangerous work environment that may need  
15 an expert's advice.

16 These workers as well as diver 14 could additionally have  
17 bidirectional electromagnetic voice communications with experts at  
18 remote locations. For surface workers, a small radio transceiver 94  
19 having an acoustic microphone/speaker 96 in compass sensor module 24  
20 can be connected to cable 80 of data transmission module 28 to allow  
21 bidirectional electromagnetic communications of information (shown as  
22 bidirectional arrow 98) between them and experts near console 19. For  
23 divers, cable communications to a commercially available diver  
24 acoustic headset 103 and microphone equipment 104 would be made over  
25 insulated conductors 101A and 102A to ports 101 and 102 on compass  
26 sensor module 24. These communications 98 and azimuth data 12 are in

1 real time to assure safe and successful completion of a task at site  
2 16 regardless of ambient visual environmental conditions (i.e.  
3 darkness, turbid water, smoke, fog, and any other opaque obscurants).

4 Acoustic transducer/transceiver 86 of data transmission module 28  
5 and transducer/transceiver 70 on craft 22 also can permit  
6 bidirectional communications in the form of bidirectional acoustic  
7 communications (shown as bidirectional arrow 100) that are transmitted  
8 through ambient water 18 between diver 14 and craft 22. Bidirectional  
9 acoustic communications 100 and azimuth data 12 sent as acoustic  
10 signals 88 are in real-time for safer and more successful operations.

11  
12 Compass and communication system 10 of the invention is small,  
13 self-contained, waterproof and ruggedized to allow its reliable  
14 operation during salvage operations or at potential underwater crime  
15 scenes for example. System 10 of the invention provides diver heading  
16 (or where diver is looking in this case) information as data 12 to  
17 topside experts and other support personnel via wire 80 or water 18  
18 transmitting acoustic signals 88. Topside personnel can monitor the  
19 direction of travel of diver 14 and area coverage if diver 14 is in a  
20 navigation mode (swimming with head aligned with body) during search  
21 and rescue sweeps at an underwater crime scene. If diver 14 stops  
22 moving during the sweeps, topside experts might determine that there a  
23 problem has developed which could be resolved from a standpoint of  
24 safety. If diver 14 finds the targeted item, diver 14 can provide  
25 topside experts at remote location 20 with a rough "mapping" of scene  
26 of the targeted area. This mapping is transferred via verbal

1 information via acoustic data signals 100 from acoustic  
2 transducer/transceiver 86 or electromagnetic information signals 98  
3 over cable 80 along with real-time azimuth data signals 12 over a  
4 possible 360° sweep from a given point as diver 14 says what is being  
5 observed. This sort of complete information could be highly useful by  
6 those involved in underwater archeological research. Complete search  
7 of an area with no overlooked spots can be coordinated.

8 Compass and communication system 10 could benefit diver 14 from  
9 having a display of azimuth data 12 at diver equipment package 17 or  
10 at a display such as referred to above in the co-pending application.  
11 Since experts at topside have real-time verbal communications and  
12 azimuth data 12 at transceiver/display console 19, diver 14 and  
13 topside experts can discuss the information and make appropriate  
14 adjustments as a situation develops.

15 Having the teachings of this invention in mind, modifications and  
16 alternate embodiments of compass and communication system 10 may be  
17 adapted without departing from the scope of the invention. Its  
18 uncomplicated, compact design that incorporates structures long proven  
19 to operate successfully lends itself to numerous modifications to  
20 permit its reliable use in hostile and demanding marine and  
21 underground applications where impaired visibility greatly complicates  
22 effective action. Compass and communication system 10 can be made  
23 from a wide variety of materials for resistance to corrosion, strength  
24 to bear up during routine abuse, and to provide long term reliable  
25 operation under a multitude of different operational conditions and  
26 requirements.

1       The disclosed components and their arrangements as disclosed  
2 herein, all contribute to the novel features of this invention.  
3 Compass and communication system 10 of the invention provides a  
4 reliable and capable means for improving the effectiveness of workers  
5 and reducing the hazards associated with operations under highly  
6 dangerous conditions that include near zero visibility. Therefore,  
7 compass and communication system 10, as disclosed herein is not to be  
8 construed as limiting, but rather, is intended to be demonstrative of  
9 this inventive concept.

10       It should be readily understood that many modifications and  
11 variations of the present invention are possible within the purview of  
12 the claimed invention. It is to be understood that within the scope  
13 of the appended claims the invention may be practiced otherwise than  
14 as specifically described.

15